

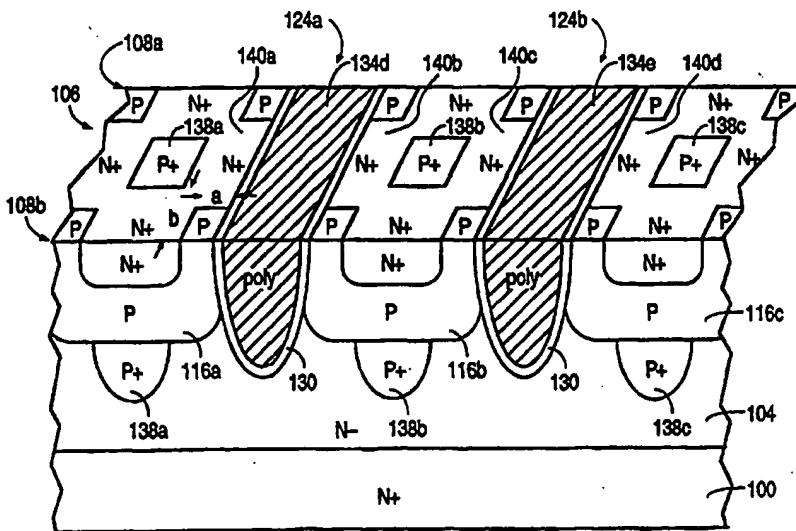


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(54) Title: TRENCHED DMOS TRANSISTOR WITH CHANNEL BLOCK AT CELL TRENCH CORNERS



## (57) Abstract

A trenched DMOS transistor has improved device performance and production yield. During fabrication the cell trench corners, i.e. the areas where two trenches intersect, are covered on the principal surface of the integrated circuit substrate with a blocking photoresist layer (142) during the source region (140a, 140b, 140c, 140d, 140e) implant step in order to prevent (block) a channel from forming in these corner areas. Punch-through is thereby eliminated and reliability improved, while source/drain on-resistance is only slightly increased. The blocking of the trench corners creates a cutout structure (142a-1) at each trench corner, whereby the source region does not extend to the trench corner, but instead the underlying oppositely-doped body region extends to the trench corner.

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TRENCHED DMOS TRANSISTOR WITH CHANNEL BLOCK  
AT CELL TRENCH CORNERS

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10     BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to trenched transistors (both FET and bipolar) and more specifically to a trenched DMOS transistor defined by intersecting trenches formed so as to have no channel in the transistor cell corner areas as defined by two intersecting trenches, so as to eliminate punch-through.

20     DESCRIPTION OF THE PRIOR ART

The well known DMOS transistors are a type of MOSFET using diffusions to form the active transistor regions. It is known to form such transistors having a trench in the substrate, the trench being lined with a thin oxide layer and filled with a conductive polysilicon to form the transistor gate structure. These transistors are typically used for power applications such as high current switching applications.

30     Prior art trenched DMOS transistors disadvantageously require a large number of masking steps to define the various transistor regions, including the tubs for the active transistor regions, the body region, the source region, and the body contact regions, each of which are separate diffusions. Additional masking steps define the oxide layers and

polysilicon portions of the transistor. Each additional masking step requires mask alignment, resulting in the possibility of alignment error, undesirably reducing yield. Additionally, the many 5 process steps (which include temperature cycles) result in diffusion of certain of the implanted ions, thus undesirably altering the lateral extent and/or depth of the diffused regions.

Such transistors are also deficient in that the 10 prior art etching processes for the trench damage the trench sidewalls, affecting the sidewall oxide thickness and thus adversely affecting transistor performance.

In the prior art typical trenched transistor, 15 another significant problem is punch-through. Punch-through is well known as an undesirable gate-controllable phenomena whereby a channel of the transistor is depleted. Punch-through typically occurs at the channel region of the transistor in the form of 20 a non-destructive leakage current, prior to avalanche breakdown. Punch-through is especially a problem with trenched DMOS transistors which tend to break down electrically at the sharp corners where two trenches intersect, as is typically the case with closed cell 25 transistors.

Punch-through tends to occur at corners because 1) at the corners, the two dimensional diffusion results in the presence of less source dopant; and 2) the electric field at the corners is stronger due to the 30 corner curvature.

#### SUMMARY OF THE INVENTION

In accordance with the invention a trenched DMOS transistor is fabricated in a substrate so that at the 35 principal surface of the substrate, at the cell corners where two trenches intersect, the source regions do not

extend to the cell corners thereby preventing the channel from forming in the cell corners. Instead, the underlying body region extends to the principal surface at the cell corners. This has been found to eliminate  
5 the above-described punch-through problem and also to improve reliability, while only slightly increasing the undesirable on-resistance.

Therefore in accordance with the invention, production yield is increased by minimizing the drain-source punch-through leakage current. This invention  
10 is applicable to any multi-cell transistor using trenches, including insulated gate bipolar transistors. Typically the invention applies to closed cell transistors having hexagonal, square, or rectangular  
15 shaped cells, but also applies to the corners of open (linear) cells where two trenches meet at e.g. a right angle to define the end of a linear cell. It has been found in accordance with the invention that production yield is increased 20% to 30% over that of the prior  
20 art, while the performance in terms of the on-resistance decreases only a few percent (less than 5%) over prior art transistors. Thus the overall performance is better due to the reduced leakage current (i.e. less punch-through). The decrease in  
25 punch-through leakage current is by a factor of 1,000 to 10,000, over the prior art; in the prior art the punch-through leakage current is about 1 microamp, whereas in accordance with the invention it is about 1 nanoamp.

30 A process to achieve a transistor structure in accordance with the invention is mostly conventional, except that the topside (plan view) configuration of the source/drain regions is defined by an additional masking step to block the source dopant implant at the  
35 corner of each transistor cell, i.e., at the point where two intersecting trenches join.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 depicts a perspective view of a portion of a transistor in accordance with the present invention.

5 Figures 2 through 7a and 8 through 13 depict a sequence of steps to form a transistor (shown in cross section) in accordance with the invention.

Figure 7b depicts a plan view of the processing step shown in Figure 7a.

10

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a prospective, (combined cross-sectional and plan) view of a multi-cell DMOS trenched transistor in accordance with the present invention.

15 It is to be understood that this view is of a portion of such a transistor, illustrating a few cells thereof. Moreover, only the transistor substrate and the associated doped regions are shown together with the trenches. That is to say, the overlying insulating  
20 layers, gate structures, and conductive interconnect are not shown for simplicity; these are illustrated in later figures.

In Figure 1, formed on the conventional N+ doped substrate 100 is an N- doped epitaxial layer 104.

25 Formed in epitaxial layer 104 are two (exemplary) trenches 124a and 124b which are conventionally etched, as described below. Lining each of trenches 124a, 124b is oxide insulating layer 130. Each trench 124a, 124b is filled with a doped polysilicon structure,  
30 respectively 134d, 134e. The principal surface of the epitaxial layer 104 is designated 106. Additional trenches intersect trenches 124a, 124b at right angles thereto, defining the intervening cells. The edges of these adjacent intersecting trenches 108a, 108b are  
35 labelled.

Illustrated in Figure 1 are two cells of a transistor which are conventionally electrically interconnected by an overlying interconnect, as described below. The first cell includes trench 124a, 5 a P doped body region 116a, an N+ doped source region 140a, and a P+ doped deep body region 138a. (The doping levels and depths of these regions are described in detail below.) The second cell includes P doped body region 116b, N+ doped source region 140b, 140c, 10 and P+ doped deep body region 138b. The third cell includes P doped body region 116c, N+ doped source region 140d, and P+ doped deep body region 138c.

The structure shown in Figure 1 is largely conventional except for the shape (both in the plan view and cross-sectional view) of the N+ regions 140a, 140b, 140c, and 140d. In each case these regions are formed so that in addition to the central P+ doped deep body regions, respectively 138a, 138b, and 138c, they also define at their corners in this case rectangular 15 "cutouts" allowing the underlying body regions respectively 116a, 116b, and 116c to extend to the substrate principal surface 106 and thereby to contact the trenches at the corner of each cell. Thus as shown in the plan view portion of Figure 1, each N+ region 20 140a, 140b 140c, 140d defines a cross-like structure due to the corner cutouts which are P regions. In contrast, in the prior art each N+ region extends (both in the plan view and in the cross-sectional view) to the side of the adjacent trench. Thus in the prior art 25 30 in a plan view the N+ regions would be squares rather than crosses. Similarly, in a cross sectional view of the prior art the N+ regions would each extend all the way to the associated trench, rather than being spaced apart therefrom by intervening P regions 116a, 116b, 35 and 116c.

In one embodiment, the dimensions "a" and "b" which are the spacing between the nearest portion of N+ region 140a, for example, and the trench 124a are each 1 micron. These dimensions are determined by the 5 process tolerance limitations; it is desirable that the N+ source region approach as close as possible to the trench while not actually contacting the trench at the trench corners. Thus in other embodiments dimensions "a", "b" are less than 1 micron, or possibly more. It 10 is desirable that dimensions "a", "b" are minimized so as to minimize the source/drain on-resistance of the transistor. The larger are dimensions "a" and "b", the larger is the undesirable source/drain on-resistance ( $R_{DSON}$ ).

15 The shape of the cutouts defined by dimensions "a" and "b" in Figure 1 need not be a square (as in Figure 1) but may be any shape, i.e., rectangular, oval, semi-circle, etc. Thus dimensions "a" and "b" need not be equal. Also, dimensions "a" and "b" depend on the 20 trench critical dimensions and the alignment technology; again "a" and "b" are desirably as small as possible.

P+ deep body regions 138a, 138b, 138c in another embodiment are shallower than the associated P body 25 regions 116a, 116b, 116c. Alternatively, the P+ deep body regions may be dispensed with since their purpose is to impart device ruggedness.

It is to be understood that the drain electrode for the transistor is conventionally formed on the 30 backside surface (not shown) of the underlying substrate 100 in Figure 1.

Figure 2 shows in cross section a first process step to form a trenched DMOS field effect transistor as depicted in Figure 1. It is to be understood that this 35 process is exemplary and other processes may be used to fabricate the final transistor structure.

A substrate 100 of Figure 1 (not shown in Figure 2) which is conventionally N+ doped has an epitaxial layer 104 which is N- doped grown on the surface of the substrate. Epitaxial layer 104 is approximately 5 to 5 10 microns ( $10^{-6}$ m) thick.

Principal surface 106 of the epitaxial layer 104 is conventionally oxidized to form a silicon dioxide layer 110 approximately 1 micron thick. Silicon dioxide layer 110 is conventionally patterned using 10 photoresist and a mask to define the P+ (deep body) regions 138a, 138b, 138d. (Note that Figures 2 to 7a and 8 to 13 do not correspond exactly to Figure 1 since the termination structure is not shown in Figure 1.) The P+ implant step is carried out by implanting boron 15 at a energy level of 60 KEV with a dosage of  $2 \times 10^{13}$  to  $1 \times 10^{16}/\text{cm}^2$ . Alternatively, boron is pre-deposited by using the boron nitride process. This forms the P+ doped regions 138a, 138b, 138d after the conventional diffusion step. (Region 138d is not a deep body region 20 in function since it is a part of the transistor termination structure.) An oxide layer 112 of approximately 0.5 micron (5000Å) thickness is also grown during this diffusion. The final depth of the P+ deep body regions is 1.5 to 3.5 microns.

It is to be understood that the P+ region 138d and 25 all portions of the transistor structure to the right thereof are the termination portion (edge) of an integrated circuit die, the vertical line at the far right being a die scribe line. The termination 30 structure disclosed herein is exemplary and not limiting.

In Figure 3, an active region mask layer is formed by covering the principal surface 106 with a photoresist layer which is then conventionally exposed 35 and patterned using a mask to leave the active mask portions 120a, 120b, 120c as shown in Figure 3.

Then in Figure 4, first a low temperature oxide undoped (LTO) layer (not shown) is deposited over the entire principal surface 106 after a cap oxide layer 300Å thick (also not shown) is grown to prevent out diffusion from the LTO layer. This low temperature oxide when patterned is used as an etch mask for defining the locations of the trenches. The LTO layer is then conventionally patterned using photoresist to form openings therethrough to define the location of trenches 124a, 124b, which upon completion are each typically 0.5 to 1.5 microns wide and pitched 5 to 10 microns apart (center-line to center-line). Then trenches 124a, 124b, are dry etched through the mask openings by reactive ion etching (RIE) to a typical depth of 1.5 microns (a typical range is 0.5 to 10 microns). Then the LTO mask layer is stripped by a buffered oxide etch. Alternatively a conventional photoresist mask is directly applied to define the trench regions, without growing the cap oxide or depositing the LTO layer. The process depends on the desired trench depth and trench etch techniques.

Then the sidewalls 126 of each trench 124a, 124b are smoothed, first using a chemical dry etch to remove a thin layer of silicon (approximately 500Å to 1000Å thick) from the trench sidewalls 126. This thin removed layer eliminates damage caused by the earlier reactive ion etching, and this etching step also rounds off the top and bottom portions of the trenches.

Then a further sacrificial oxidation step smoothes the trench sidewalls 126. A layer of silicon dioxide (not shown) is conventionally thermally grown on the sidewalls 126 of the trench to a thickness of approximately 200Å to 2,000Å. This sacrificial oxide layer is removed by a either buffer oxide etch or an HF etch to leave the trench sidewalls 126 as smooth as possible.

The gate oxide layer 130 is then grown as shown in Figure 4 lining the trench sidewalls 126 and extending over the principal surface 106, to a thickness of approximately 100Å to 1000Å.

5 Then as shown in Figure 5a a layer of polycrystalline silicon (polysilicon) is deposited to e.g. approximately 1.5 microns thickness (a typical range is 0.5 to 1.5 microns), filling trenches 124a, 124b. Next, planarization of the polysilicon layer is  
10 followed by a blanket etch to optimize the polysilicon thickness and to leave only a thickness of 0.5 micron (5,000Å). Thus a 1 micron thickness (10,000Å) of polysilicon is removed by this uniform etching.

Then the polycrystalline silicon layer (for an N-channel transistor) is doped with phosphorus chloride (POCl<sub>3</sub>) or implanted with arsenic or phosphorous to a resistivity of approximately 15 to 30 ohms per square. The polycrystalline silicon layer then is patterned to form the structures 134a, 134b, 134c and also gate electrodes 134d, 134e. This patterning uses a photoresist layer which is exposed and mask patterned. The polycrystalline silicon structures 134a, 134b, 134c in the right-hand portion of Fig. 4 are a part of the gate contact and termination portions of the  
20 transistor.  
25

Figure 5b is an enlarged view of the portion of Figure 5a at the area of polysilicon structure 134b. Illustrated is the step-like configuration of polysilicon structure 134b due to the three underlying  
30 thicknesses of oxide, respectively oxide layers 126, 112, and 110. This step-like configuration, although only shown in Figure 10b, is present also in the structures of Figures 6 to 13.

Next in Figure 6 the P body regions 116a, 116b are  
35 implanted and diffused. There is no body region implant mask, i.e. the P body implant 116a, 116b is

uniform across the wafer. Instead of a body mask, the previously formed active mask layer 120a, 120b prevents the P body implant from doping the termination region.

The P body regions 116a, 116b are boron implanted 5 at 40 to 60 KEV with a dose of  $2 \times 10^{13}$  to  $2 \times 10^{14}/\text{cm}^2$ . After diffusion, the depth of the P body regions 116a, 116b is approximately 0.5 to 2.0 micron.

Next in Figure 7a the N+ doped source regions 140a, 140b, 140c, 140d, 140e are implanted and 10 diffused, with use of a dedicated photoresist masking process, involving patterned masking layer 142. The source regions 140a, 140b, 140c, 140d, 140e are an N+ arsenic implant at 80 KEV with a dosage of typically  $5 \times 10^{15}$  to  $1 \times 10^{16}/\text{cm}^2$ . After implantation, the N+ regions 15 are diffused to a depth of approximately 0.2 to 0.5 microns and then mask layer 142 is stripped.

It is to be understood that the cross-sectional views in Figures 2 through 7a and 8 through 11 are taken through the center of P+ regions 138a, 138b of 20 Figure 1 and thus do not depict the cutout configuration of the N+ source regions.

Figure 7b is a plan view of the step depicted in Figure 7a but showing additional portions of the structure. In Figure 7b a number of cells of the 25 transistor are depicted. However, the termination structure which is depicted in the right-hand portion of Figure 7a is not shown in Figure 7b; instead only active cells are depicted, i.e., the left-hand portion of Figure 7a. Shown in Figure 7b are the trenches 30 124a, 124b, and an additional trench 124c, as well as the trenches defining the next row of cells which are trenches 124e, 124f, 124g and 124h. Also depicted are the intersecting trenches 108a, 108b, as depicted in Figure 1 and an additional intersecting trench 108c. 35 These trenches thereby define the depicted square cells.

Of most importance, depicted in Figure 7b is the blocking mask layer 142 in Figure 7a which defines the lateral extent of the N+ source regions. This blocking mask layer is shown by the cross-hatched numerous small 5 rectangular areas in Figure 7b. The small rectangular areas, i.e. 142a, 142b, 142c in the center of each of the cells, define the underlying P+ deep body topside contact regions 138a, 138b, 138c. The corresponding structure in the upper row of cells in Figure 7b is not 10 labeled but is similar.

This portion of the structure is essentially conventional. However, the significant portions of blocking mask 142 are the additional rectangular masking layer portions designated (for the first row of 15 cells in Figure 7b) respectively 142a-1, 142a-2, 142b-1, 142b-2, and 142c-1, 143c-2. These define the N+ region cutouts depicted in the top view in Figure 1, as can be understood by comparing Figure 7b to Figure 1. The dimensions of each small rectangular mask portion, 20 for example, portion 142a-1, are "d" by "e" where e.g. "d" is 3.5 microns and "e" is 1.7 microns. These dimensions were selected to achieve the desired amount of overlap which is typically a 1 micron overlap (dimension "a") as shown in Figure 1. This overlap 25 assumes that the trench width is 1.5 microns, which is dimension "f" in Figure 7b.

The trenches for the first row of cells are in one embodiment conventionally offset from those in the second row of cells in Figure 7b, although this is not 30 essential to the invention.

Next, as shown in Figure 8 after mask layer 142 is conventionally stripped, a BPSG (boro-phosphosilicate glass) layer 144 is conventionally formed to a thickness of approximately 0.5 to 1.5 microns over the 35 entire principal surface 106 and over the polysilicon structures 134a, 134b, 134c, 134d, 134e. BPSG layer

144 is covered with a photoresist layer (not shown) which is patterned after exposure and then the underlying BPSG layer 144 and oxide layer 112 are etched so as to leave the BPSG regions 144a, 144b, ..., 5 144e, between which are defined the transistor contact areas. Then, a reflow step smooths the corners on the BPSG layer structures 144a, ..., 144e.

Then as shown in Figure 10a, conventional interconnect metal masking steps are performed, 10 involving covering the entire principal surface 106 with aluminum conventionally alloyed with small amounts of silicon. This aluminum layer is then conventionally patterned using a mask to define the metallization areas 154a, 154b, 154c, 154d. These metallization 15 areas are respectively the active (source-body) contact 154a, gate finger contact 154b, field plate 154c, and equipotential ring (EQPR) 154d. After scribing, EQPR 134d is shorted to the substrate 104.

Figure 10b is an enlarged view of a portion of 20 Figure 10a (similar to Figure 5b) and showing the stepped oxide structure 110, 112 underlying polysilicon field plate 134b and field plate contact 154c.

The next step is pad masking in Figure 11. This involves surface passivation using for instance nitride 25 or PSG (phosphosilicate glass) layer 160 deposited over the entire structure and then conventionally masked with portions thereof thereinafter removed as in Figure 11 to open pad areas for connection of bonding wires to the earlier formed active metallization 30 contact 154a and to the other metallization areas as needed. (The steps described above in conjunction with Figures 8 to 11 are conventional.)

Figure 12 is a cross-section depicting many of the same structures as shown in Figure 11 but at a 35 different portion of a cell, thus better illustrating the polysilicon gate runner connection 134f in the

central portion of the figure. Gate runner connection 134f is typically located at the die perimeter. The gate runner 134f conventionally electrically connects all of the gates. At the location of gate runner 5 134f, the cross section of Figure 12 is along an "L shape" (dog leg) in plan view (not shown) to better illustrate the gate runner 134f along a length of its trench.

Figure 13 illustrates an additional cross-section 10 showing other portions of the termination. In this case the field plate 154c which is a termination conductive structure conventionally provided for power transistors, connects to the source-body region metal contact 154a by a metal cross-over 154e which crosses 15 over the BPSG insulating layer 144 in the termination region to the field plate contact 154c and the field plate 134b.

Also in accordance with the invention, each cell next to a gate finger is a dummy (nonactive due to 20 having no channel) cell. Thus the entire cell row e.g. 134e in Figure 11 adjacent to a gate finger 134a consists of dummy cells. This structure is achieved by the same mask as the blocking implant mask in Figure 7a so that no N+ source implant is made adjacent 25 polysilicon trench filling 134e. Thus the dummy cells are implemented by providing the doped regions immediately to the right of trench 124b as having no active regions and hence serving as portions of a dummy cell. The dummy cells have been found to improve 30 reliability and also device ruggedness. These dummy cells are dispensed with in other embodiments.

The above description of the invention is 35 illustrative and not limiting; for instance the same steps may be used with the conductivity types of the various semiconductor regions reversed also to form a transistor in accordance with the invention. Other

modifications will be apparent to one of ordinary skill in the art in the light of this disclosure and are intended to fall within the appended claims.

CLAIMS

We claim:

1. A trenched transistor cell comprising:

5           a substrate of a first conductivity type and defining at least two intersecting trenches; an insulating layer lining the trenches; a conductive material filling the trenches; a source region of the first conductivity type and extending from a principal surface of the substrate adjacent to the trenches into the substrate; and

10           a body region of a second conductivity type opposite the first type and extending from the principal surface adjacent to the trenches into the substrate;

15           wherein at a corner of the cell defined by the two intersecting trenches, the source region is spaced apart from the trenches.

20           2. The cell of Claim 1, wherein the source region is spaced apart from the corner of the cell by at least 0.1 microns and at the corner of the cell the body region is in contact with the trenches.

25           3. The cell of Claim 1, wherein the cell includes at least four corners each defined by two intersecting trenches, and the source region is spaced apart from each corner of the cell.

30           4. The cell of Claim 1, wherein a width of the trench is less than about 1.5 microns.

35           5. The cell of Claim 1, wherein the body region extends into the substrate less than about 1.5 microns.

6. The cell of Claim 1, wherein the source region extends into the substrate less than about 0.5 microns.

5 7. The cell of Claim 2, wherein at the corner of the cell, the source region is not in contact with the trenches.

10 8. The cell of Claim 1, further comprising an additional body region of the second conductivity type and extending from the principal surface at a central portion of the source region into the substrate, to a depth different than that of the body region.

15 9. The cell of Claim 2, wherein at the principal surface the body region defines a rectangular area in contact with the trenches.

20 10. The cell of Claim 1, further comprising a plurality of similar cells arranged in rows, and including a gate finger connecting the conductive material filling the trench in each row, and wherein a row of the cells adjacent the gate finger is inactive.

25 11. A method of forming a transistor cell comprising:

30 providing a semiconductor substrate having a first region of a first conductivity type extending from a principal surface of the substrate;

forming at least two trenches in the substrate and extending into the substrate from the principal surface, the trenches intersecting to define a corner of the cell;

35 forming a body region in the substrate having a second conductivity type, the body region

extending into the substrate alongside the at least two trenches;

5 forming a masking layer over the principal surface and covering the principal surface at the corner; and

10 forming a source region of the first conductivity type and extending into the substrate from the principal surface alongside the at least two trenches, an extent of the source region being defined by the masking layer, the source region thereby being spaced apart from the corner.

12. The method of Claim 11, wherein the step of forming semiconductor regions comprises implanting ions 15 in the substrate.

13. The method of Claim 11, wherein the step of forming semiconductor regions comprises pre-depositing dopant in the substrate.

20 14. The method of Claim 11, further comprising, after the step of forming the trenches the steps of:

growing a layer of oxide on the sidewalls of the trenches; and

25 stripping off the layer of oxide, thereby smoothing the sidewalls and rounding off the bottom portion of the trenches.

15. The method of Claim 14, further comprising, 30 before the step of growing the layer of oxide, isotropically dry etching the sidewalls of the trenches, thereby smoothing the sidewalls and rounding off the top and bottom portion of the trenches.

35 16. The method of Claim 11, further comprising forming an additional body region of the second

conductivity type in the substrate and extending from the principal surface at a central portion of the source region into the substrate to a depth different than that of the body region.

5

17. The method of Claim 11, wherein the step of forming a masking layer comprises defining a rectangular shaped mask portion at each corner of the cell.

10

18. The method of Claim 11, further comprising the step of determining an area of a portion of the masking layer covering the principal surface at the corner as being dependent on a width of the trenches  
15 and process alignment techniques.

## AMENDED CLAIMS

[received by the International Bureau on 26 September 1995 (26.09.95);  
original claims 11 and 14 amended; new claims 19-21 added;  
remaining claims unchanged (5 pages)]

5

1. A trenched transistor cell comprising:  
a substrate of a first conductivity type and  
defining at least two intersecting trenches;

an insulating layer lining the trenches;

10

a conductive material filling the trenches;

a source region of the first conductivity type  
and extending from a principal surface of the  
substrate adjacent to the trenches into the  
substrate; and

15

a body region of a second conductivity type  
opposite the first type and extending from the  
principal surface adjacent to the trenches into the  
substrate;

20

wherein at a corner of the cell defined by the  
two intersecting trenches, the source region is  
spaced apart from the trenches.

25

2. The cell of Claim 1, wherein the source region  
is spaced apart from the corner of the cell by at least  
0.1 microns and at the corner of the cell the body region  
is in contact with the trenches.

30

3. The cell of Claim 1, wherein the cell includes  
at least four corners each defined by two intersecting  
trenches, and the source region is spaced apart from each  
corner of the cell.

4. The cell of Claim 1, wherein a width of the  
trench is less than about 1.5 microns.

35

5. The cell of Claim 1, wherein the body region  
extends into the substrate less than about 1.5 microns.

6. The cell of Claim 1, wherein the source region extends into the substrate less than about 0.5 microns.

7. The cell of Claim 2, wherein at the corner of 5 the cell, the source region is not in contact with the trenches.

8. The cell of Claim 1, further comprising an additional body region of the second conductivity type 10 and extending from the principal surface at a central portion of the source region into the substrate, to a depth different than that of the body region.

9. The cell of Claim 2, wherein at the principal 15 surface the body region defines a rectangular area in contact with the trenches.

10. The cell of Claim 1, further comprising a plurality of similar cells arranged in rows, and 20 including a gate finger connecting the conductive material filling the trench in each row, and wherein a row of the cells adjacent the gate finger is inactive.

11. A method of forming a transistor cell 25 comprising:

providing a semiconductor substrate having a first region of a first conductivity type extending from a principal surface of the substrate;

30 forming at least two trenches in the substrate and extending into the substrate from the principal surface, the trenches intersecting to define a corner of the cell;

forming an insulating layer lining the trenches;

35 forming a conductive electrode in the trenches overlying the insulating layer;

forming a body region in the substrate having a second conductivity type, the body region extending into the substrate alongside the at least two trenches;

5 forming a masking layer over the principal surface and covering the principal surface at the corner; and

10 forming a source region of the first conductivity type and extending into the substrate from the principal surface alongside the at least two trenches, an extent of the source region being defined by the masking layer, the source region thereby being spaced apart from the corner.

15 12. The method of Claim 11, wherein the step of forming semiconductor regions comprises implanting ions in the substrate.

20 13. The method of Claim 11, wherein the step of forming semiconductor regions comprises pre-depositing dopant in the substrate.

25 14. The method of Claim 11, wherein the step of forming the insulating layer comprises the steps of:

growing a layer of oxide on the sidewalls of the trenches; and

stripping off the layer of oxide, thereby smoothing the sidewalls and rounding off the bottom portion of the trenches.

30 15. The method of Claim 14, further comprising, before the step of growing the layer of oxide, isotropically dry etching the sidewalls of the trenches, thereby smoothing the sidewalls and rounding off the top and bottom portion of the trenches.

16. The method of Claim 11, further comprising forming an additional body region of the second conductivity type in the substrate and extending from the principal surface at a central portion of the source region into the substrate to a depth different than that of the body region.

17. The method of Claim 11, wherein the step of forming a masking layer comprises defining a rectangular shaped mask portion at each corner of the cell.

18. The method of Claim 11, further comprising the step of determining an area of a portion of the masking layer covering the principal surface at the corner as being dependent on a width of the trenches and process alignment techniques.

19. A trenched transistor cell comprising:  
20        a substrate of a first conductivity type and  
              defining at least two intersecting trenches;  
              an insulating layer lining the trenches;  
              a conductive material filling the trenches;  
              a source region of the first conductivity type  
              and extending from a principal surface of the  
25        substrate adjacent to the trenches into the  
              substrate; and  
              a body region of a second conductivity type  
              opposite the first type and extending from the  
              principal surface adjacent to the trenches into the  
              substrate;  
30        wherein at a corner of the cell defined by the  
              two intersecting trenches, the source region is  
              spaced apart from both of the trenches, and at a  
              side of the cell away from the corner of the cell,  
              the source region is adjacent one of the trenches.

20. The cell of Claim 1, wherein at a side of the cell away from the corner of the cell and defined by one of the trenches, the source region is adjacent that one of the trenches.

5

21. The method of Claim 11, wherein the step of forming the source region includes forming the extent of the source region to be adjacent to one of the trenches at a side of the cell away from the corner of the cell.

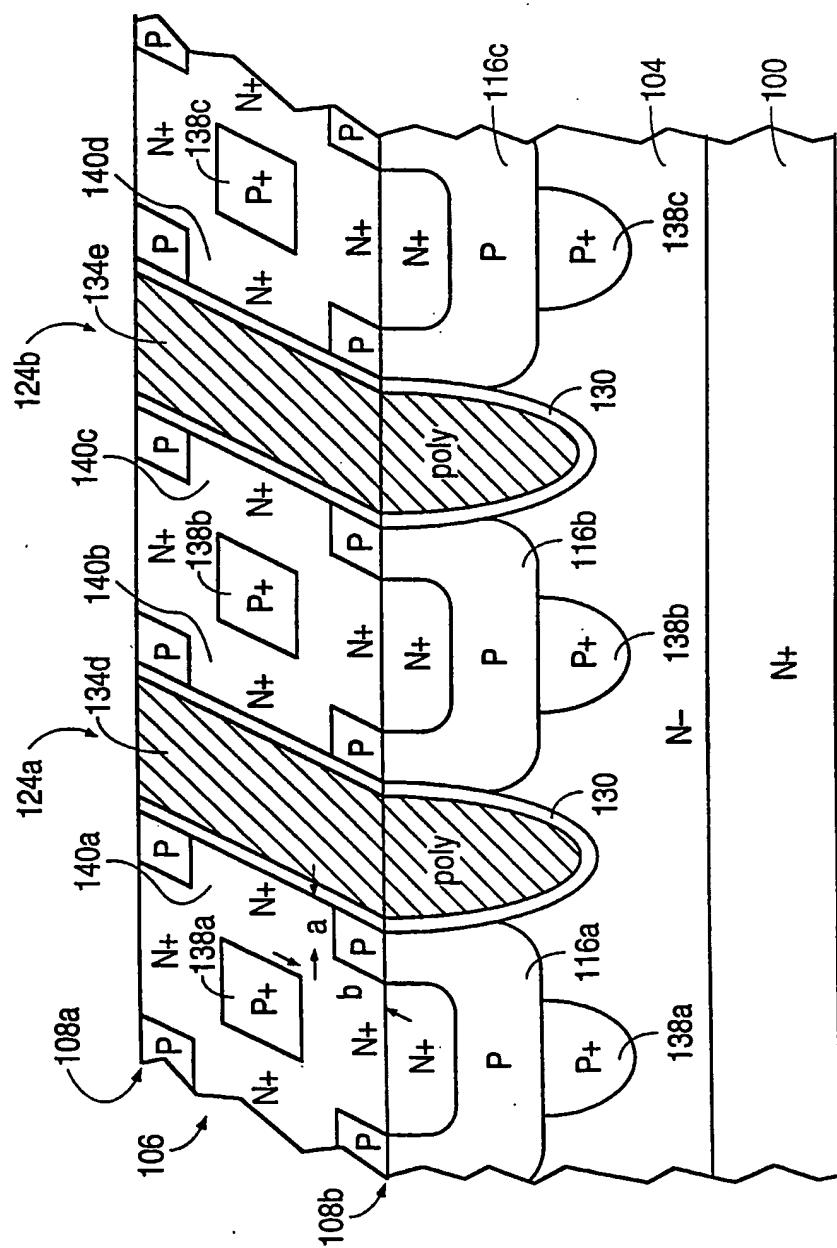
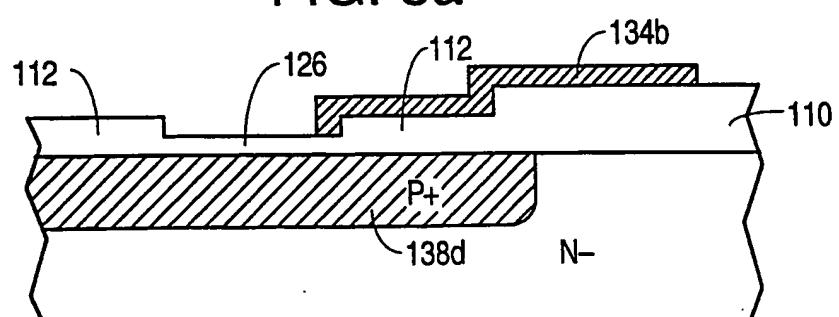
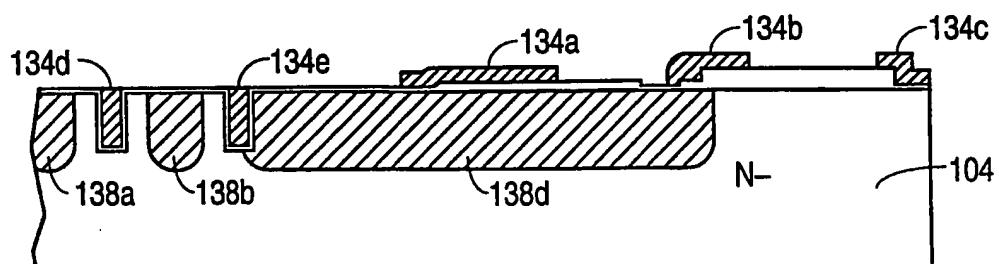
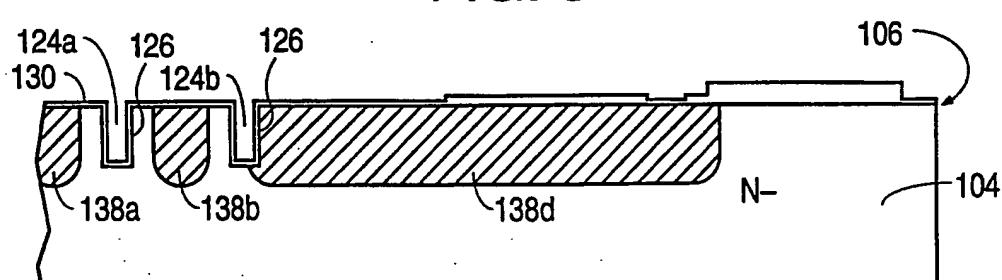
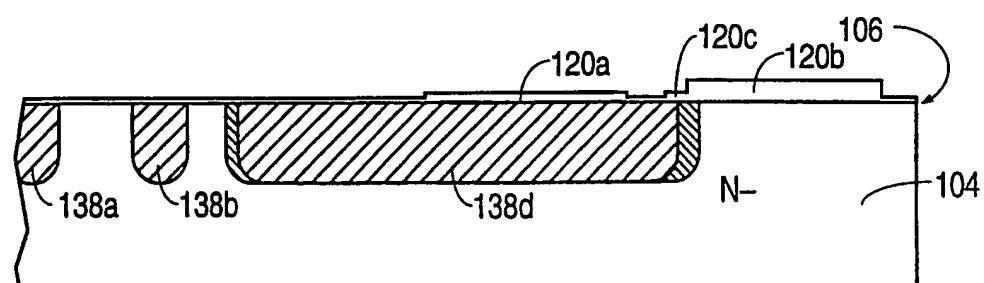
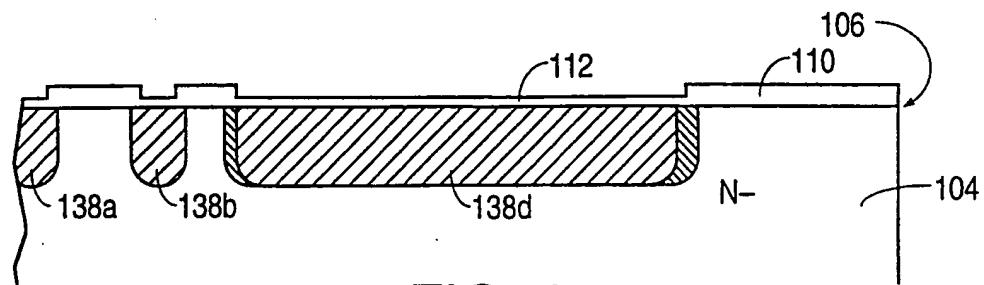


FIG.



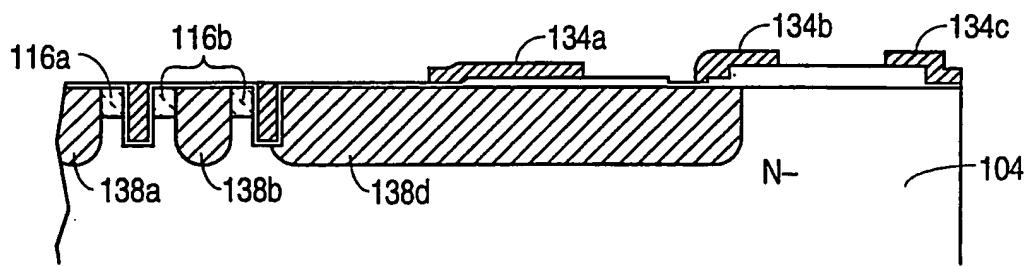


FIG. 6

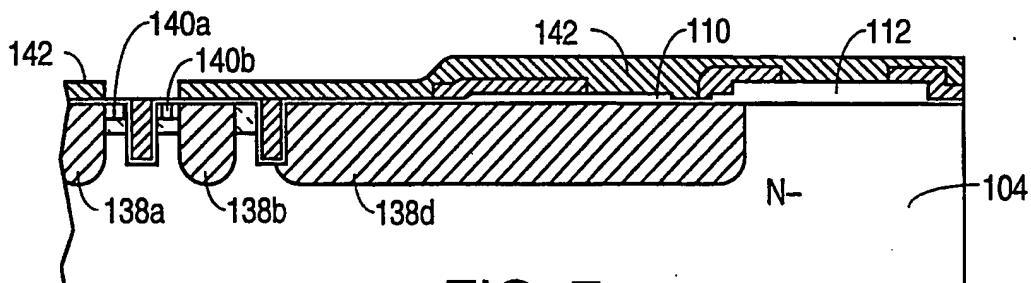


FIG. 7a

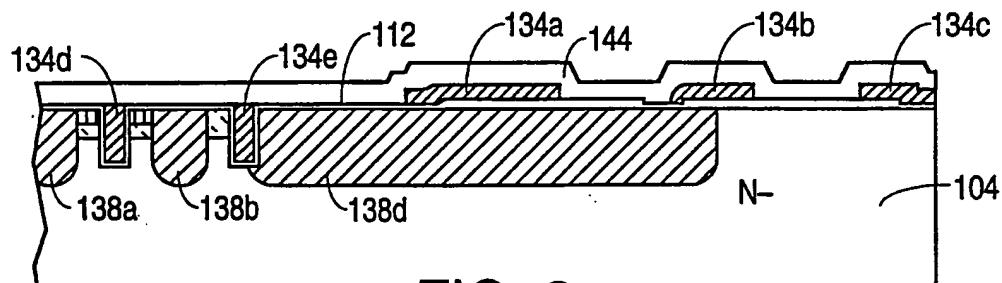


FIG. 8

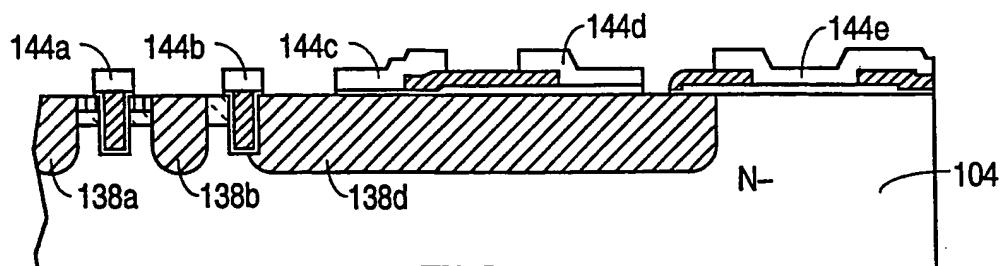


FIG. 9

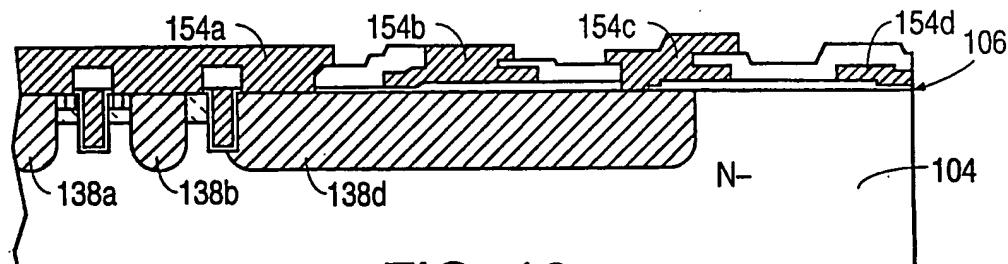


FIG. 10a

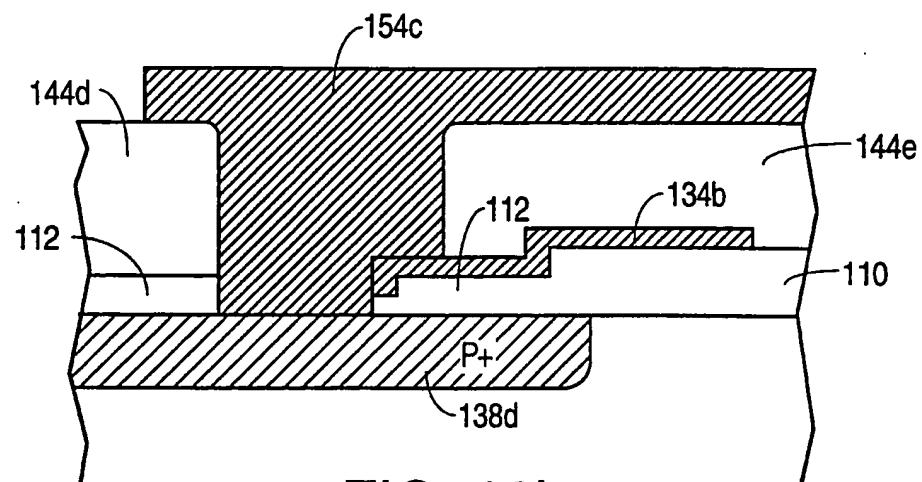


FIG. 10b

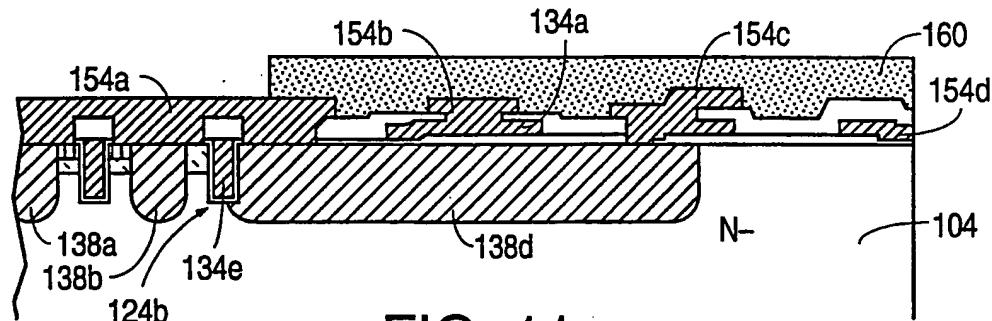


FIG. 11

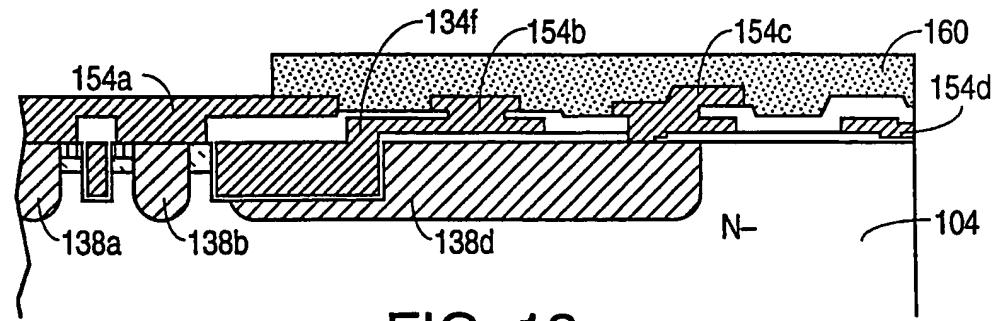
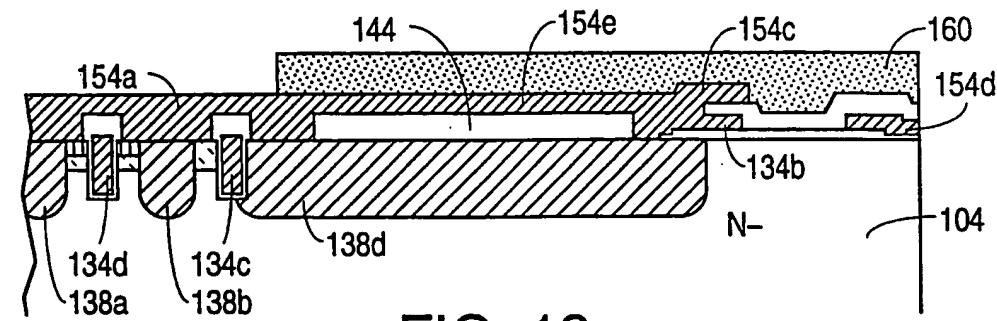
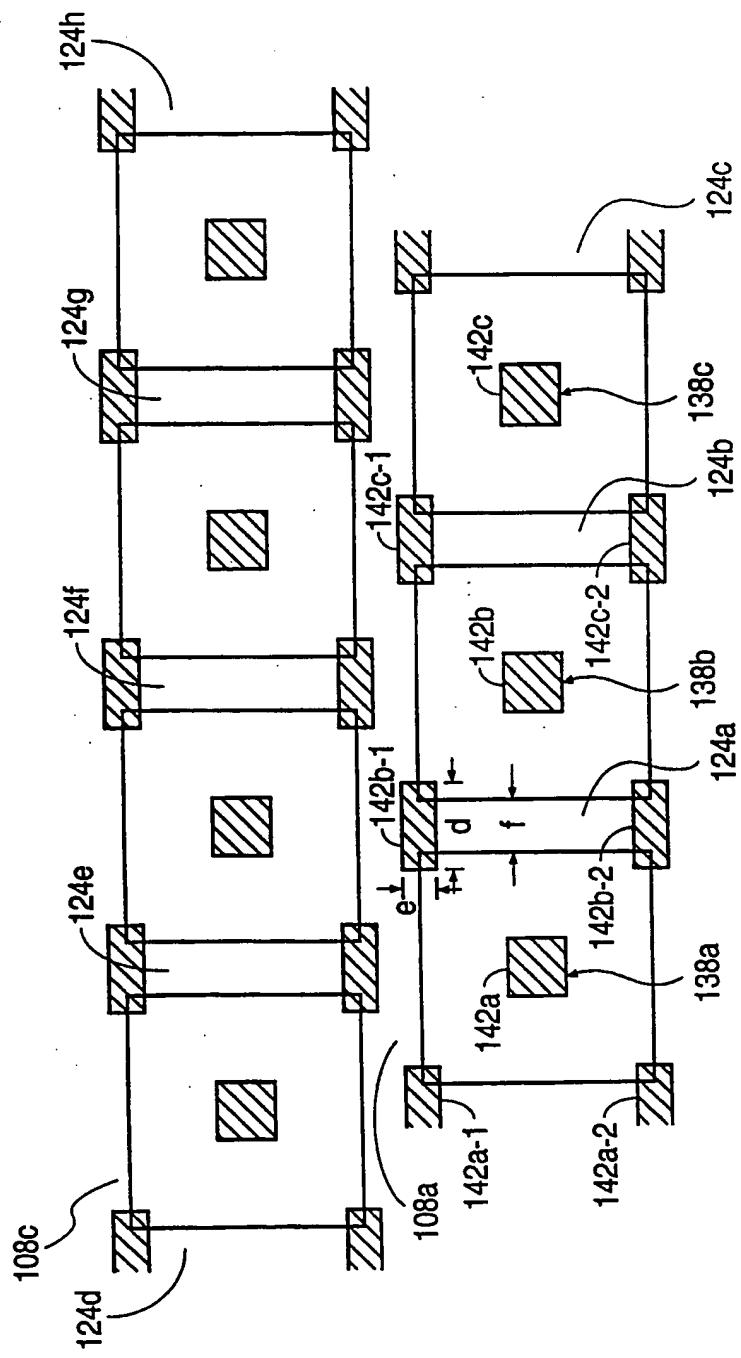


FIG. 12

FIG. 13  
4/5

**FIG. 7b**

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US95/06701

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :HOIL 29/00, 29/06, 29/76, 21/265, 21/302  
US CL :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 257/331, 332, 341, 401, 520, 622;  
437/48, 66, 67, 78, 79, 225

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,567,641 (BALIGA ET AL) 04 FEB 1986, col. 7, lines 15-60, and col. 8, lines 33-58	11-18

Further documents are listed in the continuation of Box C.  See patent family annex.

Special categories of cited documents:	
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*E*	earlier document published on or after the international filing date
*L*	document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
*O*	document referring to an oral disclosure, use, exhibition or other means
*P*	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"A"	document member of the same patent family

Date of the actual completion of the international search

28 AUGUST 1995

Date of mailing of the international search report

31 AUG 1995

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Authorized officer  
*Edward Wojciechowicz*  
EDWARD WOJCIECHOWICZ  
Telephone No. 703-308-4898

**INTERNATIONAL SEARCH REPORT**

International application No. PCT/US95/06701
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**A. CLASSIFICATION OF SUBJECT MATTER:**  
**US CL :**

257/331, 332, 341, 401, 520, 622;  
437/48, 66, 67, 78, 79, 225